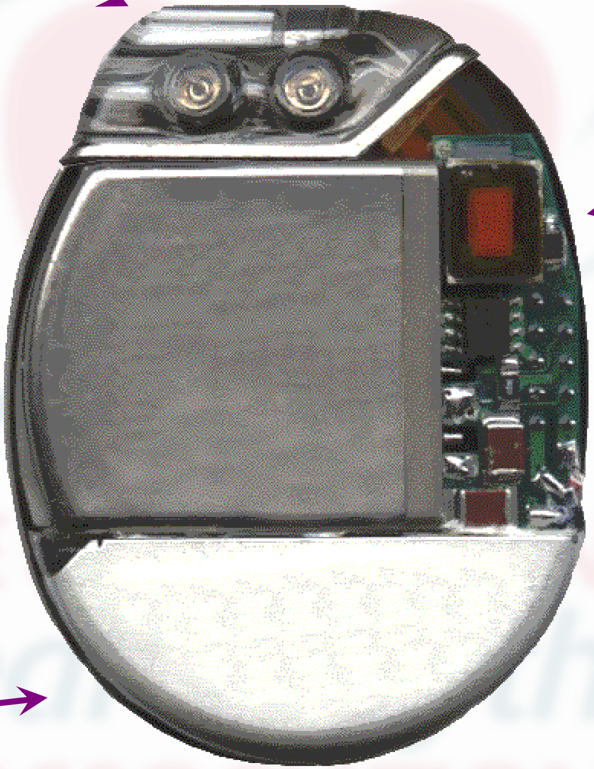
Fundamentals of ICDs

Haran Burri, MD
Wim Stoffelen

Contents

- General concepts
- Sensing
- Discriminators
- Therapies

Anatomy of an ICD



Header

Transformer

Multiplies voltage
(e.g up to 750V)

Battery

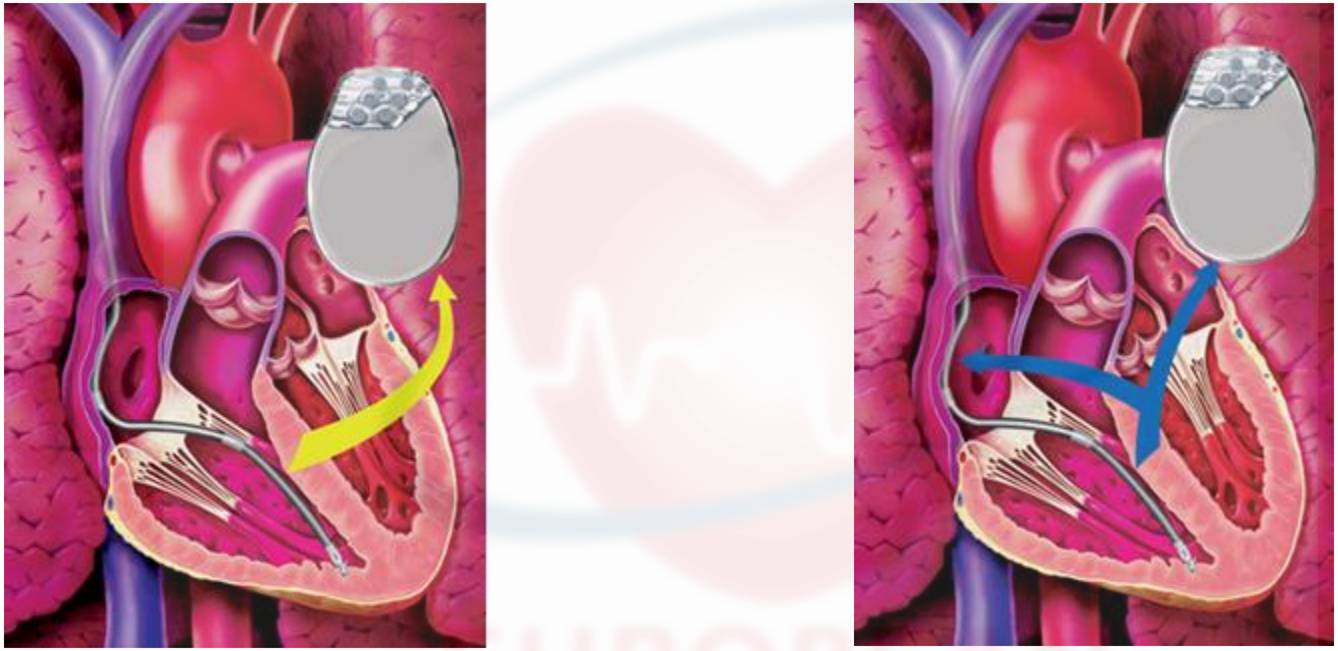
Provides low-voltage energy
(e.g. 3.2V)

Circuitry

Capacitor

Stores energy
before the shock

ICD Leads: Single coil versus dual coil



Dual coil leads may have a slightly lower DFT, but are usually more difficult to extract (adherences with SVC wall)

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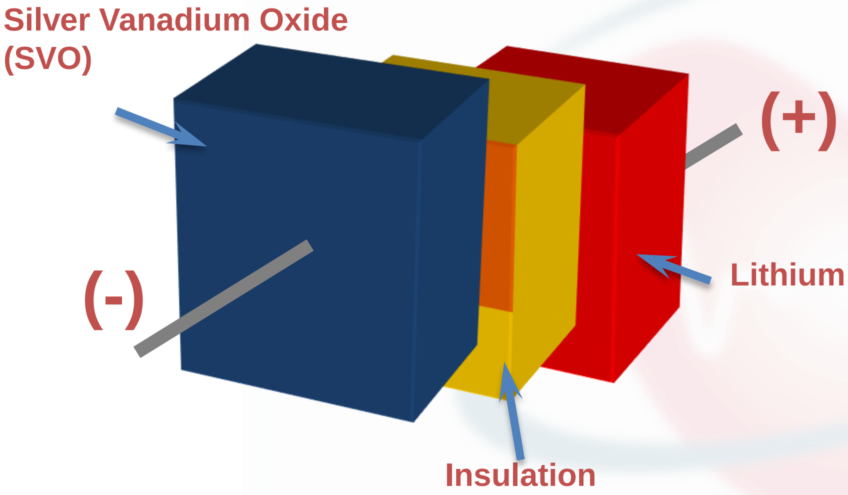
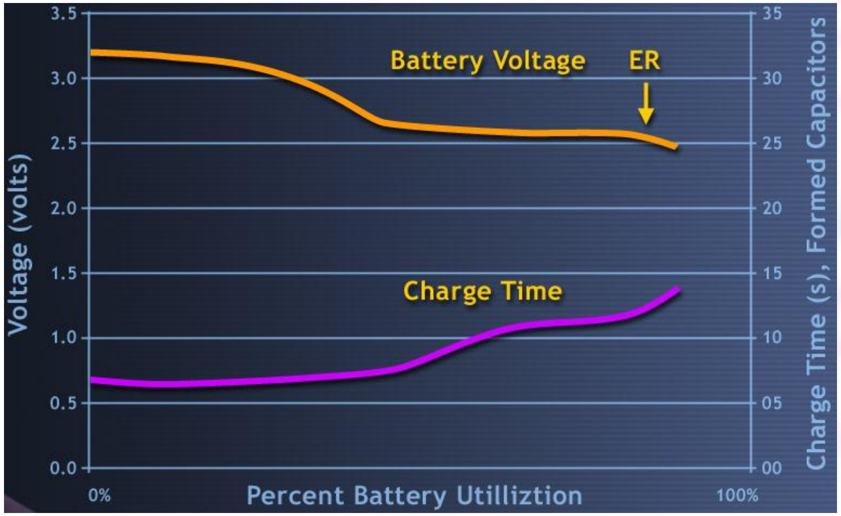
The battery

The battery



- Consists of a electro-chemical cell (pump) and an internal resistor
- Depending on the chemistry, power and capacity of the battery will be different



ENERGY IN A CAPACITOR

The energy stored in a capacitor is directly proportional to its capacitance and directly proportional to the square of the voltage.

$$\boxed{W = \frac{C.V^2}{2}}$$

W = energy in joule (J)

C = capacitance in farad (F)

V = voltage in volt (V)

EXAMPLE :

A capacitor of 120µF is initially charged to 200V. It delivers a pulse which is truncated at a tilt of 65%. What is the energy delivered to the patient ?

Solution :

The tilt is 200V x 0.65 = 130V

At the end of the pulse the voltage is still 200V - 130V = 70V

Energy at the start $W_1 = \frac{120.10^{-6} \times 200^2}{2} = 2.4$ joule

Energy at the end $W_2 = \frac{120.10^{-6} \times 70^2}{2} = 0.3$ joule

Delivered to the patient : 2.4J - 0.3J = 2.1J

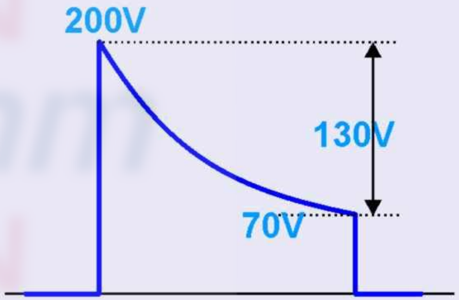
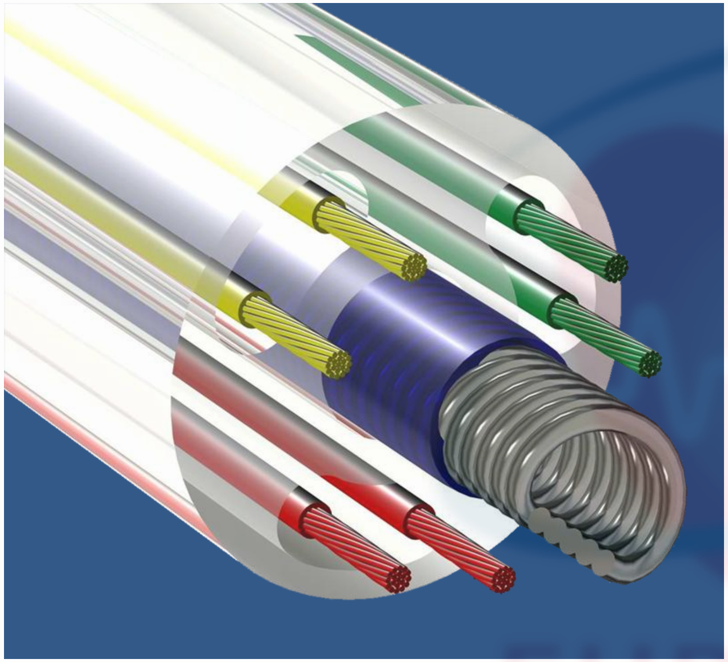
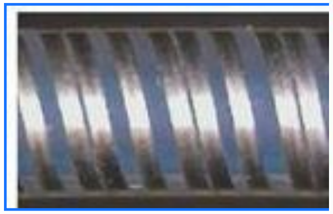


Fig. 3.14

ICD Leads: design





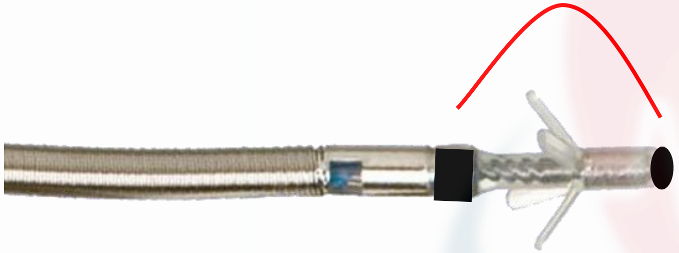
Multilumen design

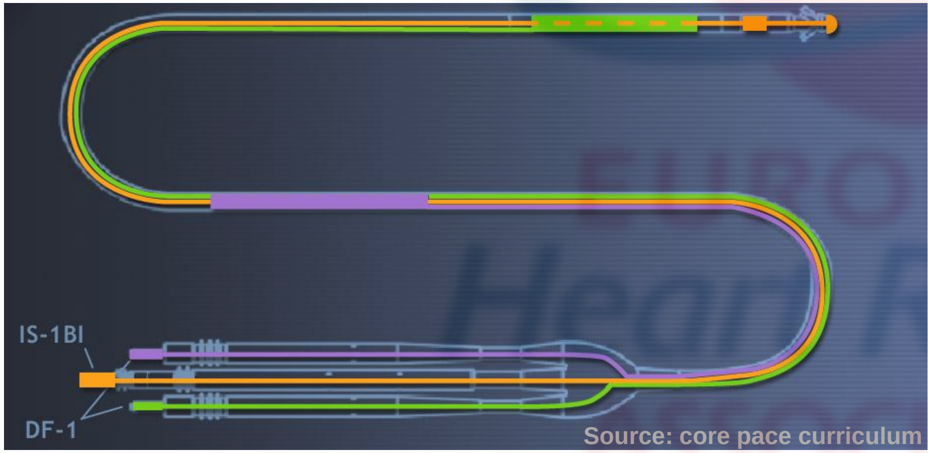
- Insulation: Polyurethane/ Silicone/ Optim
- P/S electrode and coil: metal alloys
- Covered coils for less tissue ingrowth (backfill between coils or Goretex coating)
- Shock coils have a low impedance (e.g. 40-60Ω) in order to increase current delivery

True bipolar versus integrated bipolar ICD leads

True bipolar

(Dedicated ring for pacing/sensing)

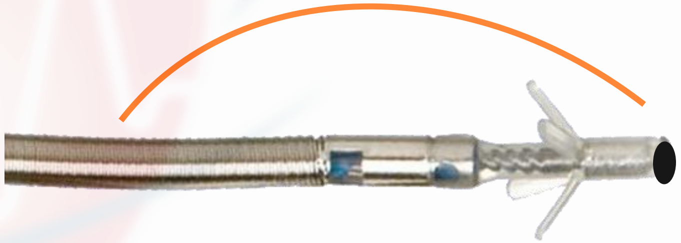


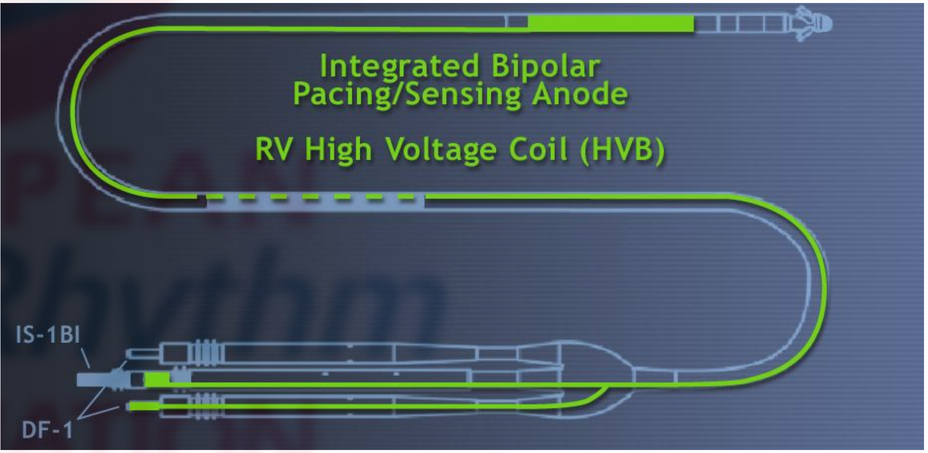


Source: core pace curriculum

Integrated bipolar

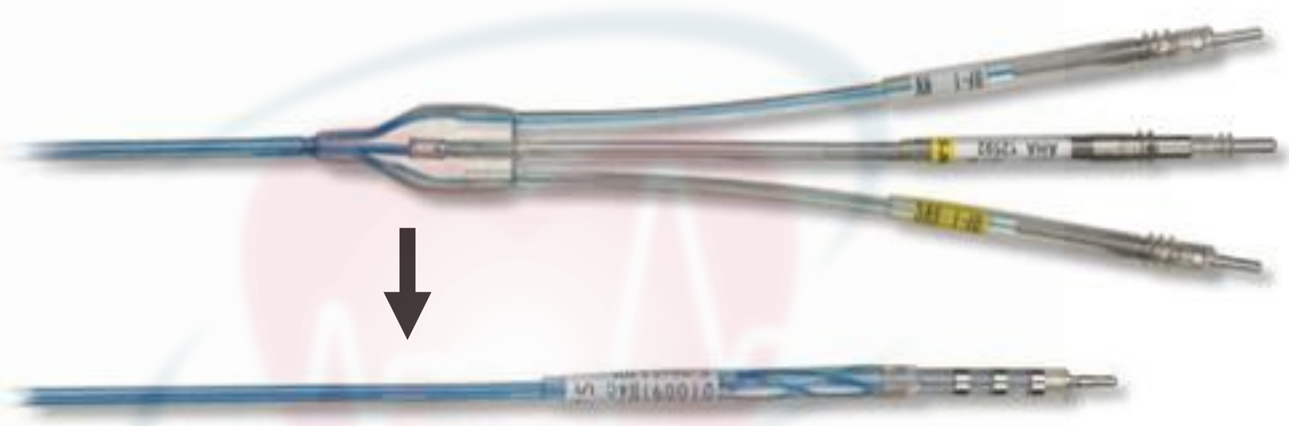
(RV coil is part of the pace/sensing circuit)




Integrated Bipolar Pacing/Sensing Anode
RV High Voltage Coil (HVB)
IS-1BI
DF-1

Connector standards

DF-1 / IS-1

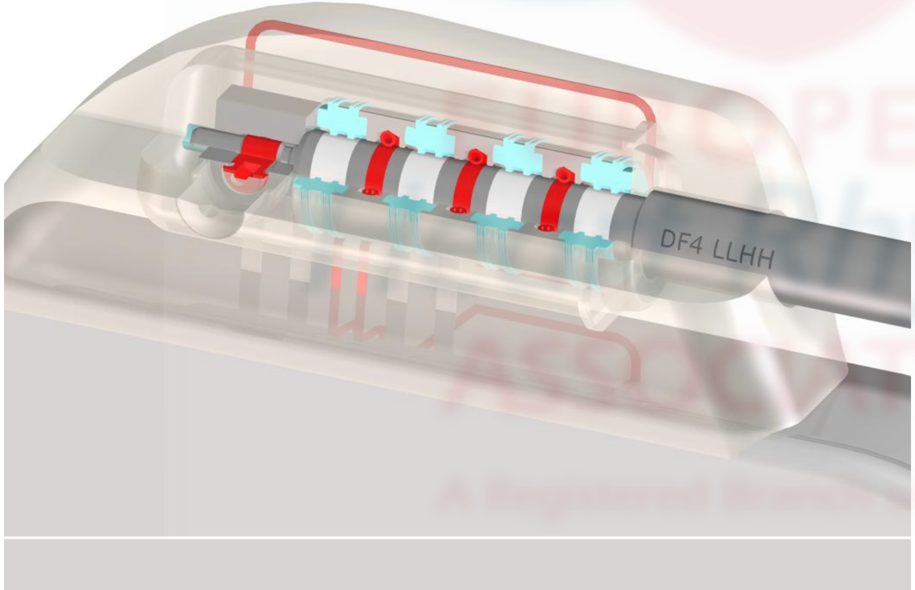


DF-1

IS-1

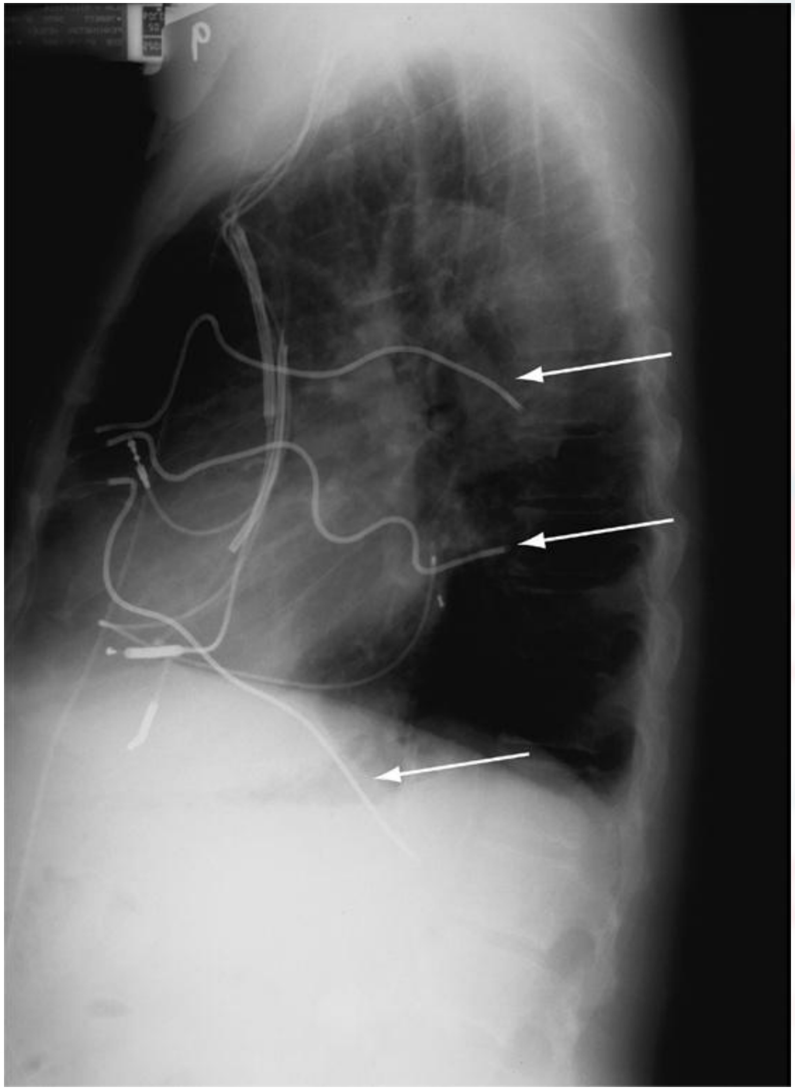
DF-1

DF-4



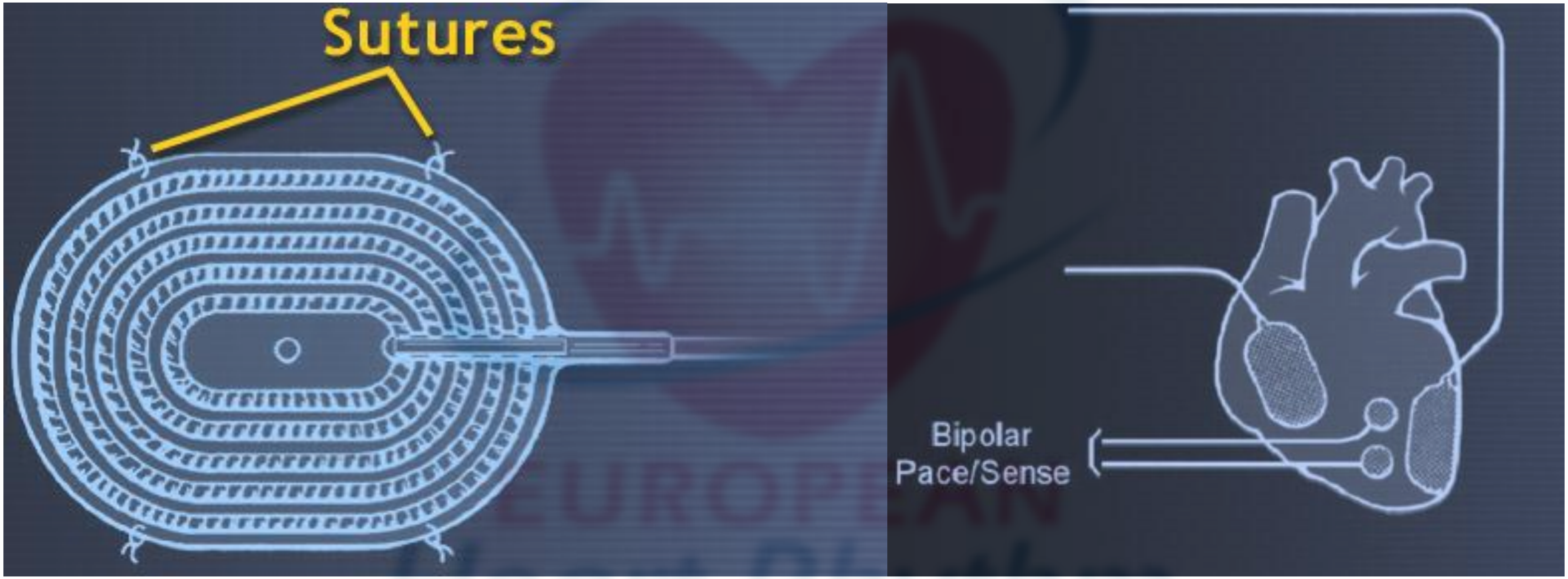
L =low-voltage contact
H =high-voltage contact

Subcutaneous Array



Lateral chest X-ray of a SQ-array Implanted for high DFT

Epicardial ICD leads



Almost never used anymore !

Source: core pace curriculum

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Contents

- General
- **Sensing**
- Discriminators
- Therapies

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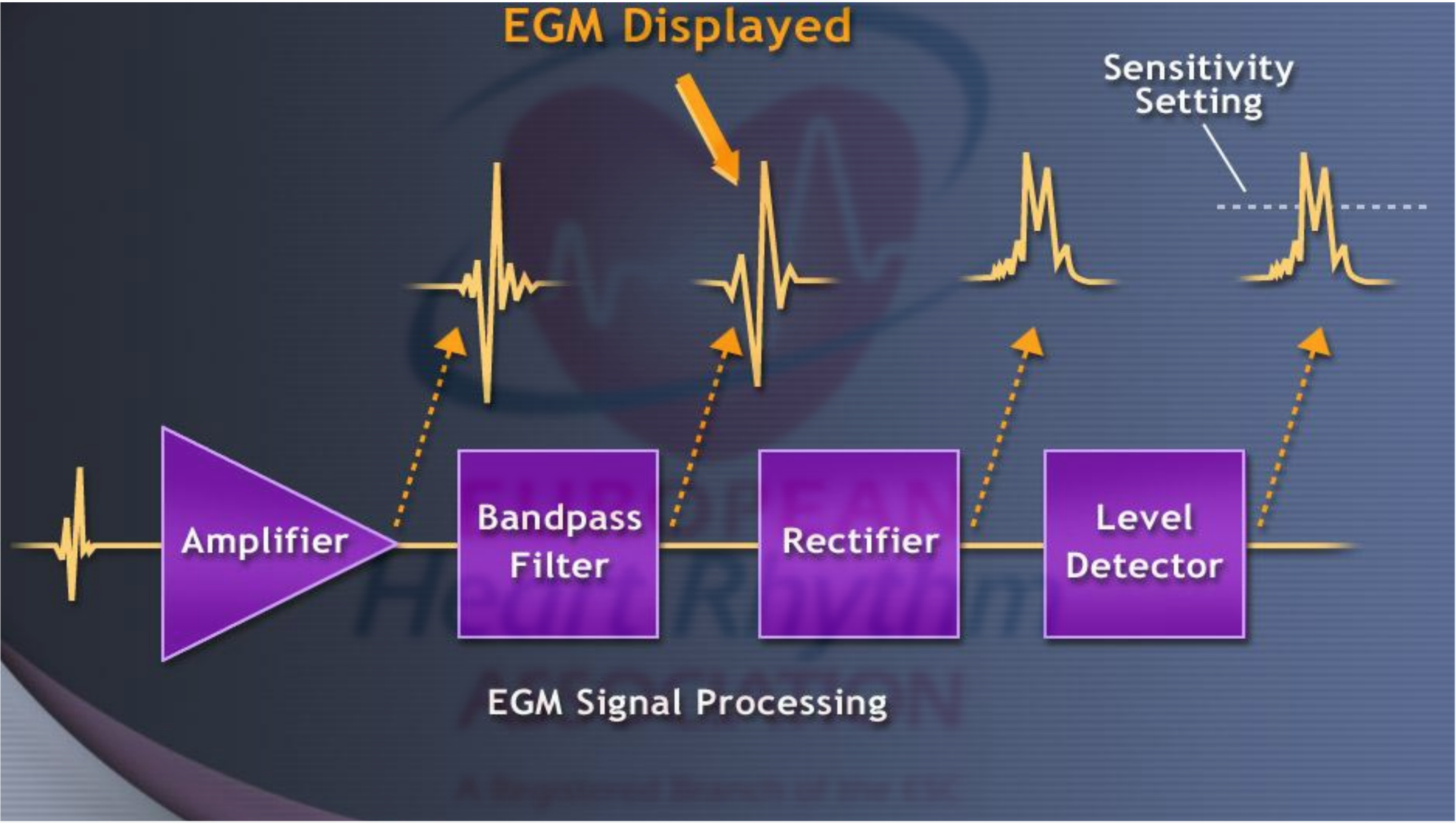
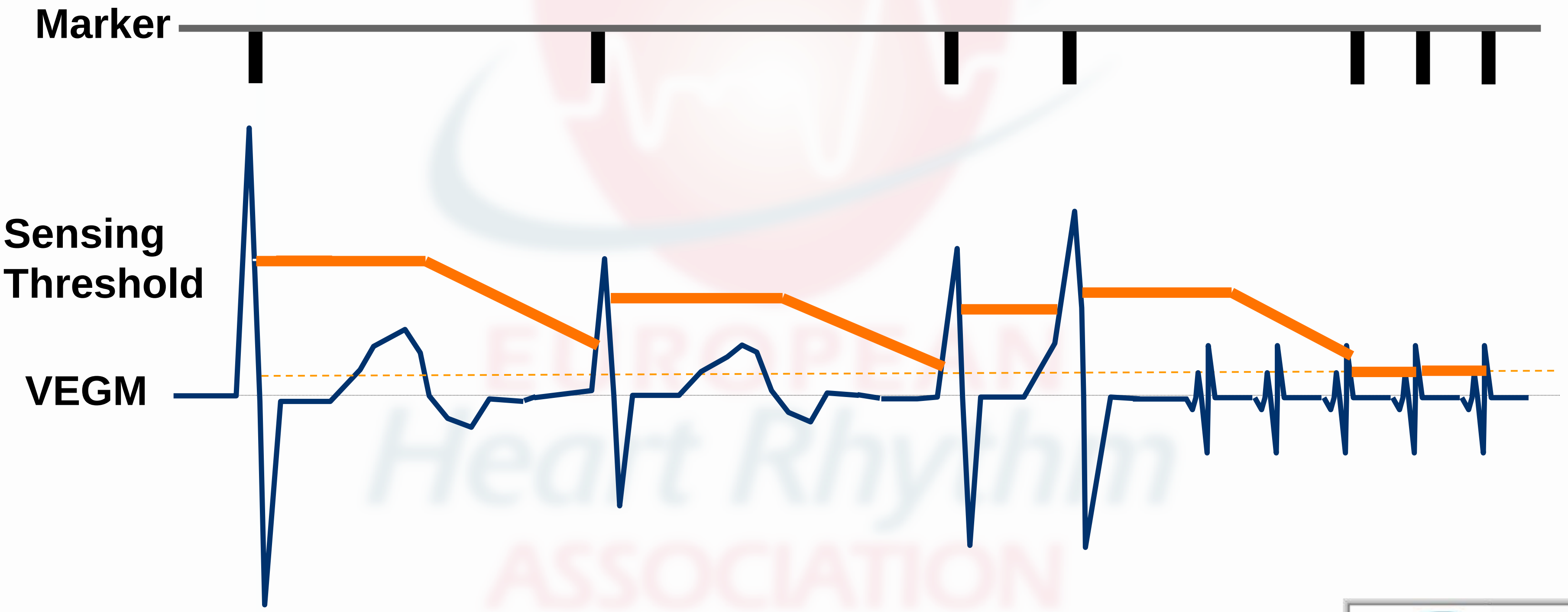
The Sensing Circuit



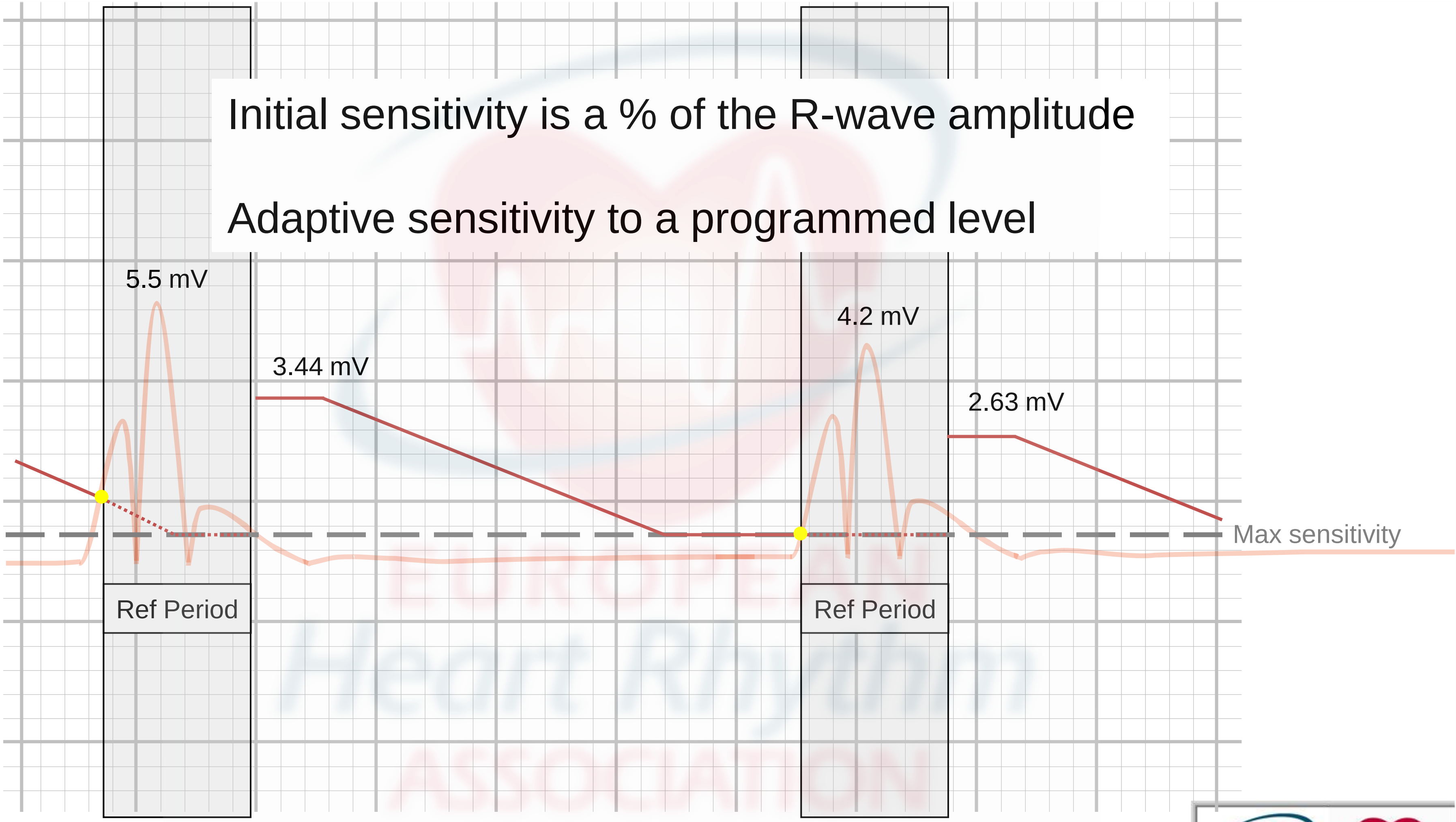
Source: core pace curriculum

Sensing Systems

An ICD needs a different sensing system compared to a pacemaker to avoid undersensing of low amplitude signals (such as VF), but without oversensing signals such as the T-wave



ICD sensing



Initial sensitivity is a % of the R-wave amplitude

Adaptive sensitivity to a programmed level

Contents

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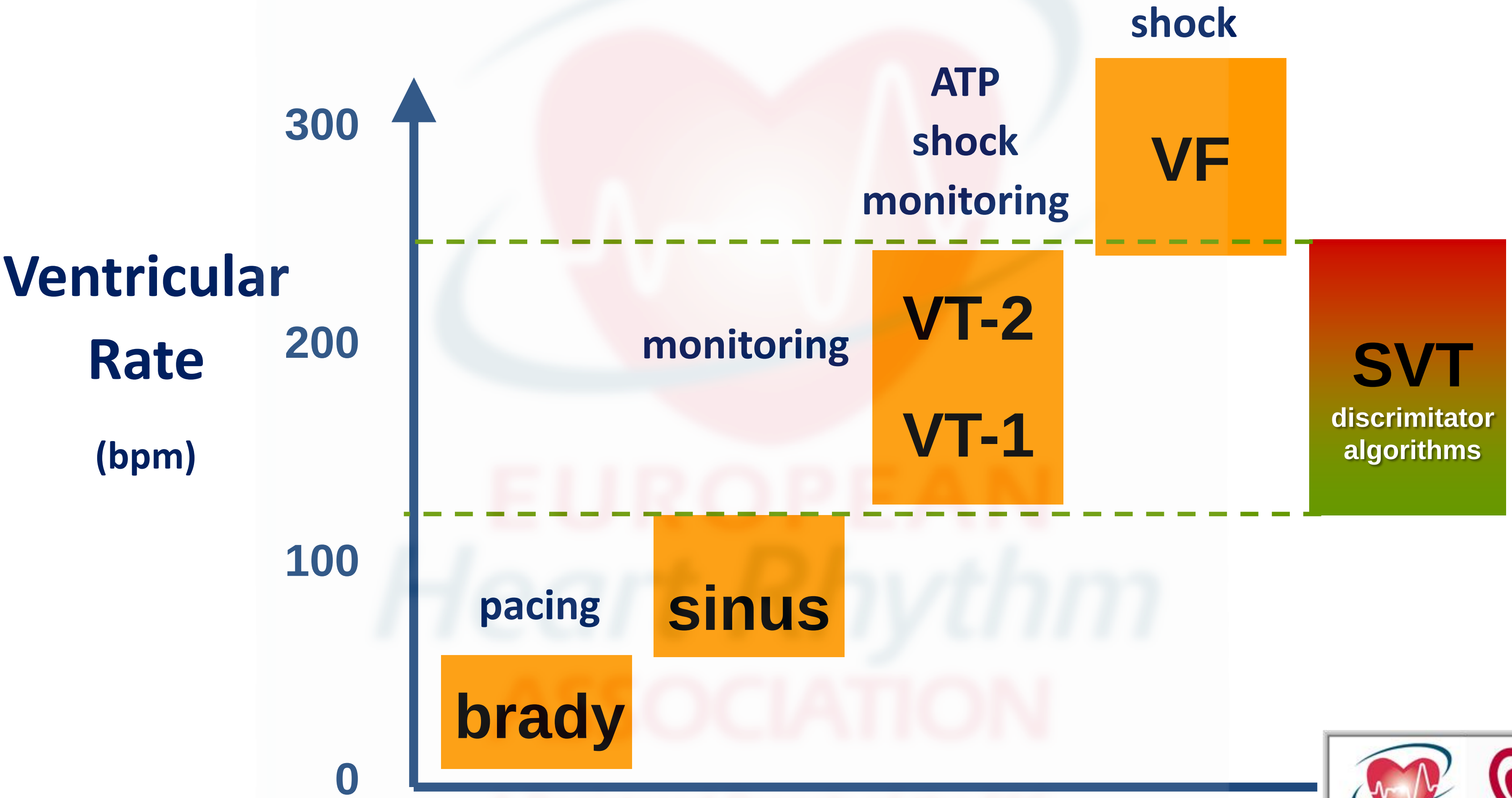
Adapted rate zones



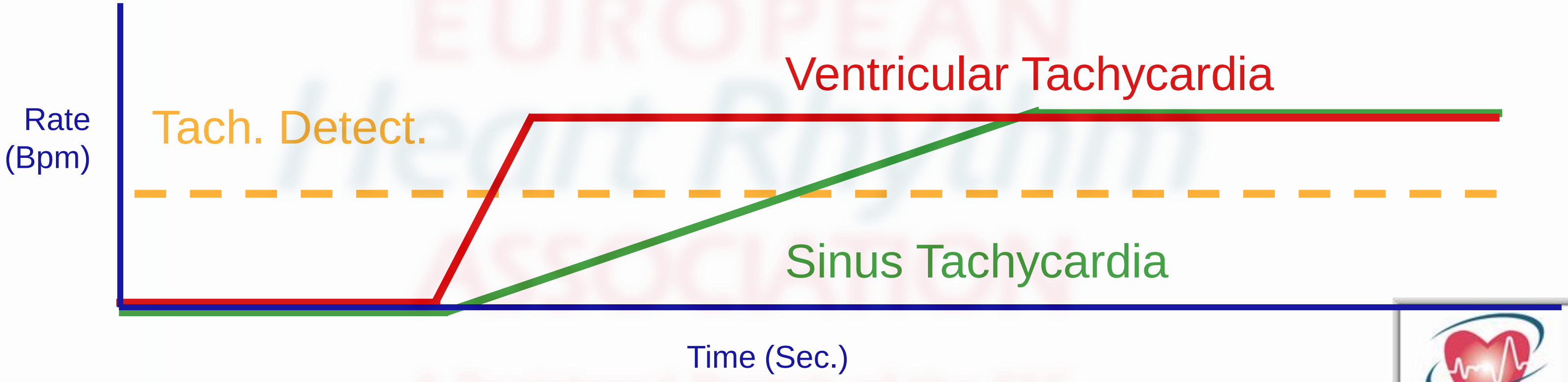
Ventricular Rate (bpm)

Discriminators

- Algorithms that increase specificity of arrhytmia detection (VT vs. SVT)
- All companies combine these discriminators differently to reduce inappropriate shocks
- Examples:
  - Sudden Onset
  - Interval Stability
  - Morphology
  - A:V relationship

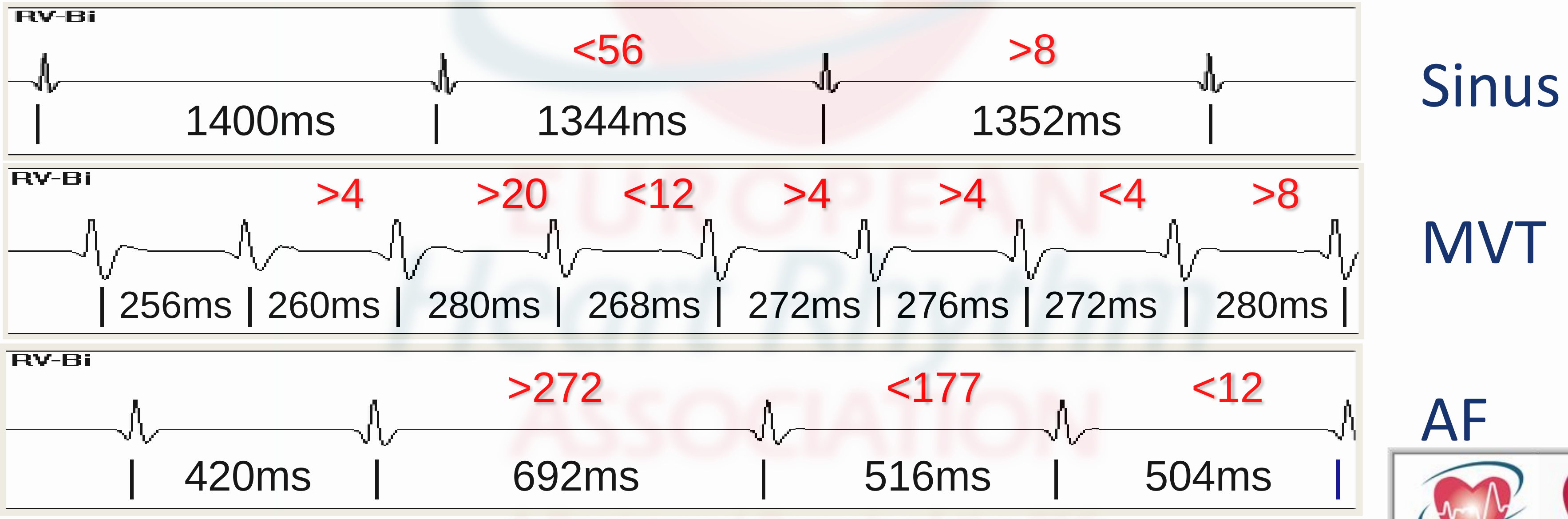
Sudden Onset

- Designed to discriminate sinus tach. from VT in patients whose maximum sinus rate can exceed the rate of their slowest VT
- Evaluates onset of the tachycardia
- Usually, VT starts abruptly while sinus tach. has a more gradual onset

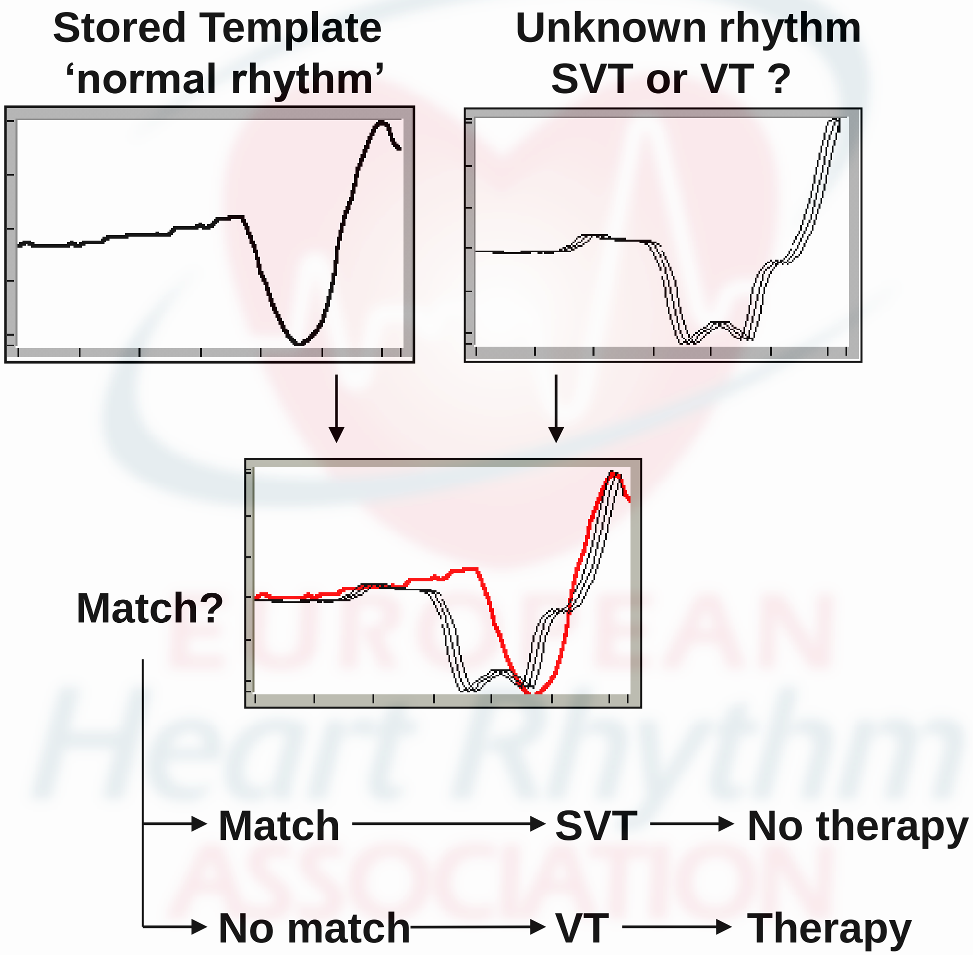


Interval Stability

- Feature designed to discriminate between VT and rapidly-conducted AF
- Measures variations in cycle length during the tachycardia (VT=regular, AF=irregular)



Morphology Discrimination



Stored Template
'normal rhythm'

Unknown rhythm
SVT or VT ?

Match?

→ Match → SVT → No therapy

→ No match → VT → Therapy

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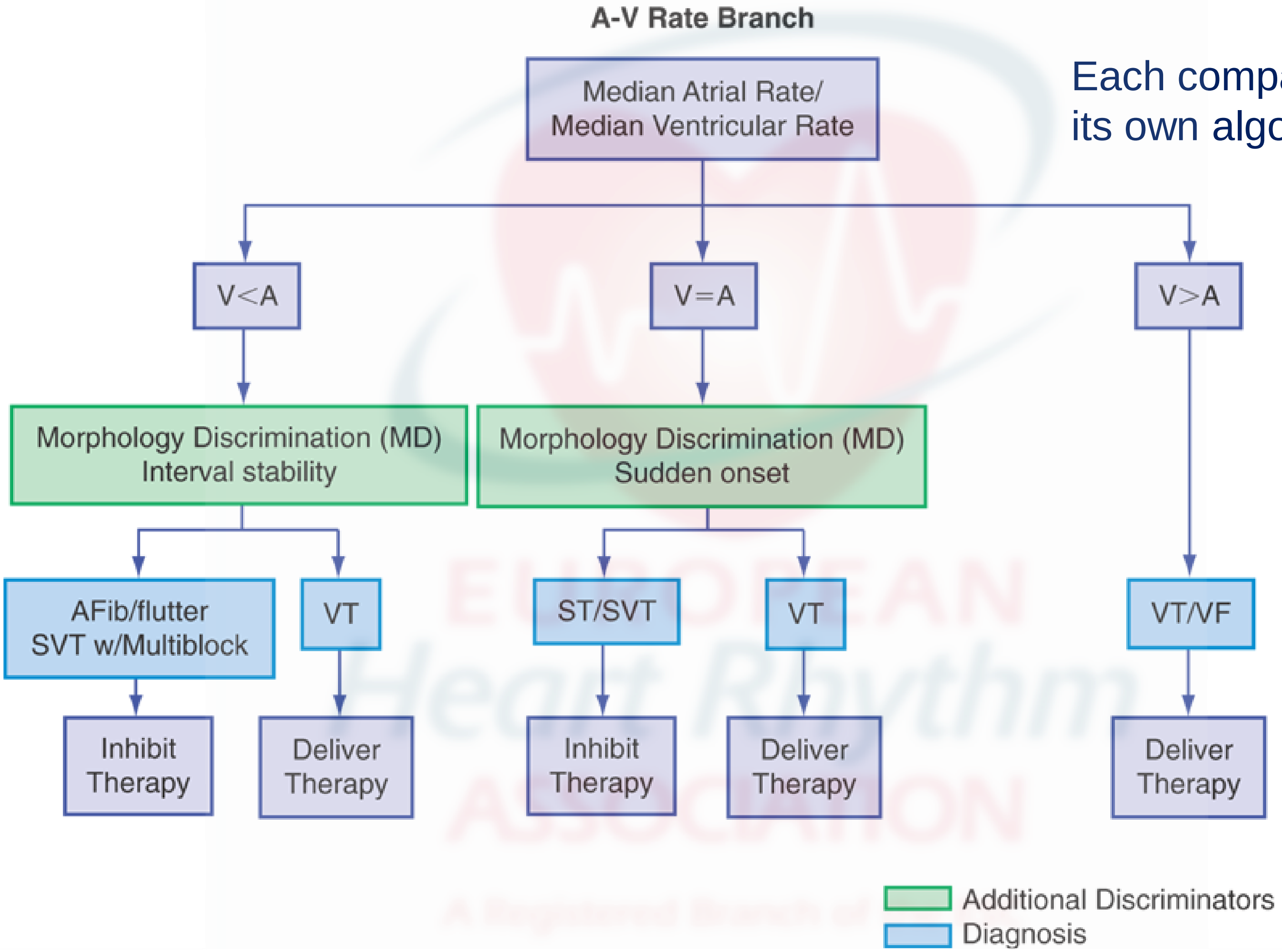
Dual chamber discriminators



A-V Rate Branch

Median Atrial Rate/ Median Ventricular Rate

V<A

V=A

V>A

Morphology Discrimination (MD) Interval stability

Morphology Discrimination (MD) Sudden onset

AFib/flutter SVT w/Multiblock

VT

ST/SVT

VT

VT/VF

Inhibit Therapy

Deliver Therapy

Inhibit Therapy

Deliver Therapy

Deliver Therapy

🟩 Additional Discriminators
🟦 Diagnosis

Each company has its own algorithm!

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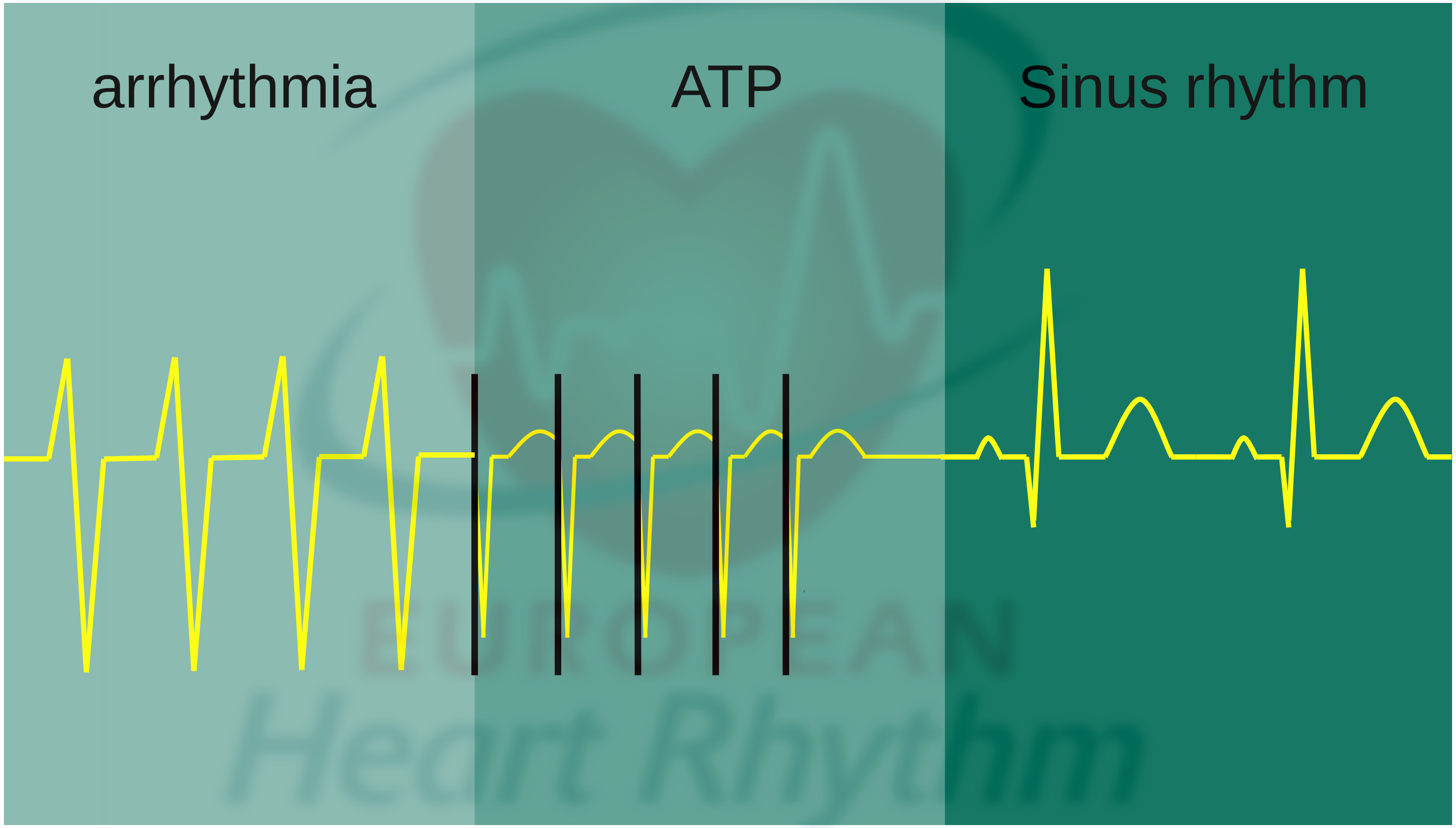
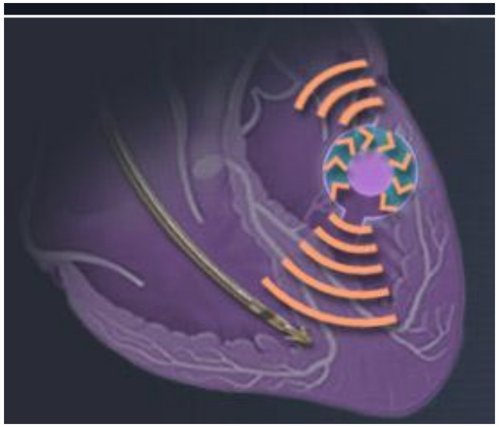
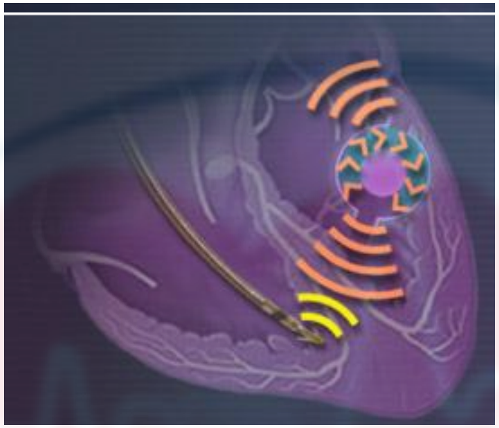
Anti-tachycardia pacing (ATP)



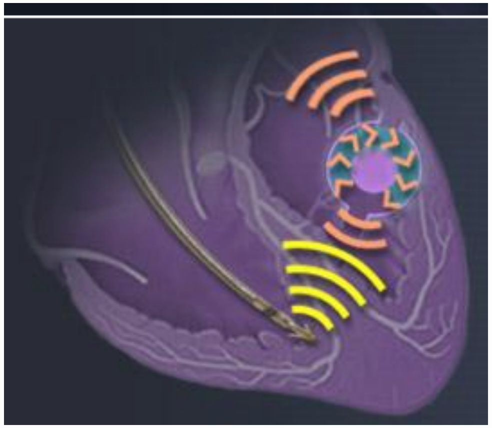
ATP mechanism



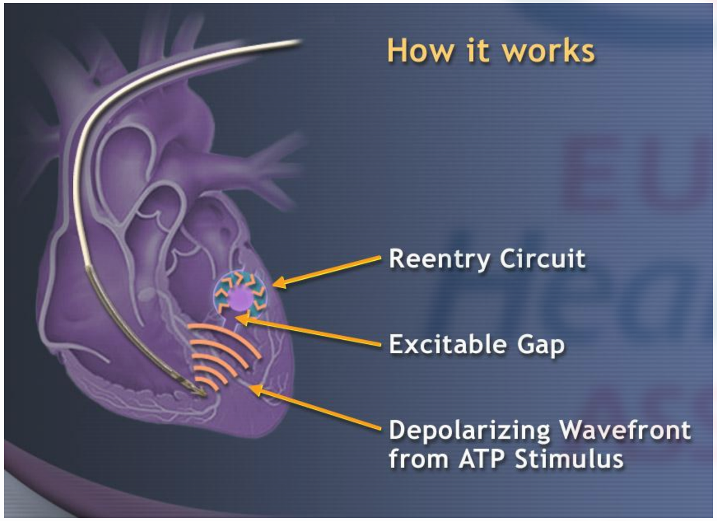
Re-entrant VT



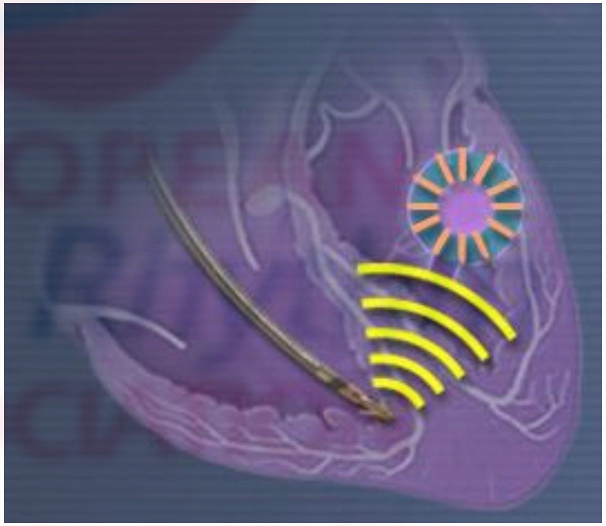
ATP delivered faster than VT. Wavefronts collide



Subsequent pulses with collision closer to circuit



Penetration of the VT circuit during the excitable gap

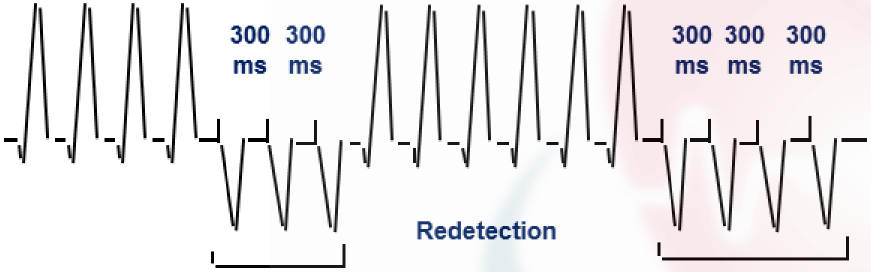


Arrhythmia termination

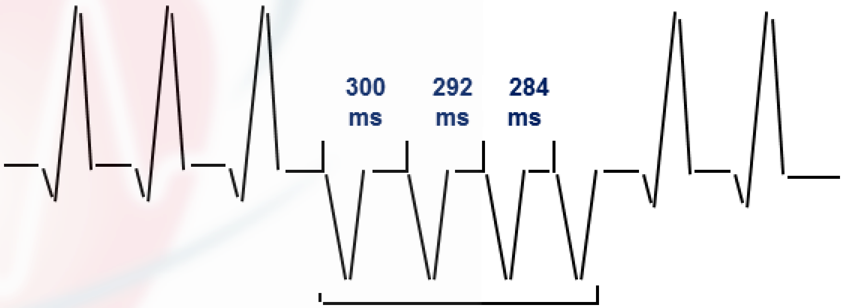
Source: core pace curriculum

ATP Modes

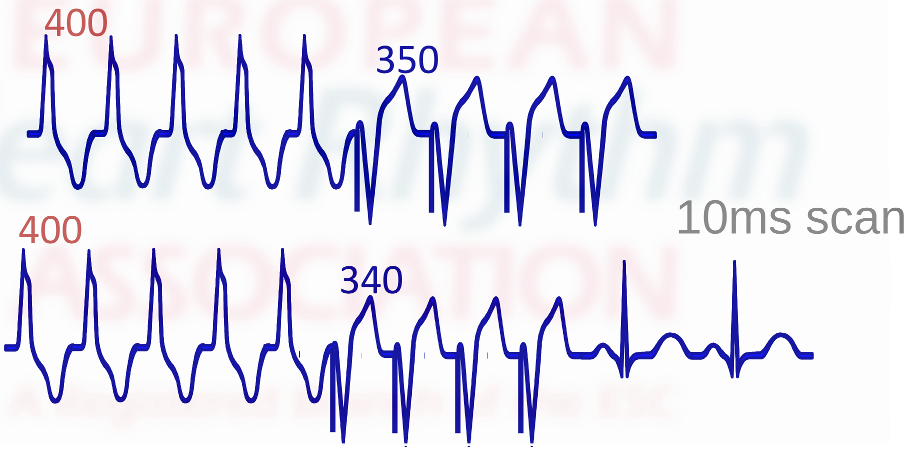
Burst



Ramp

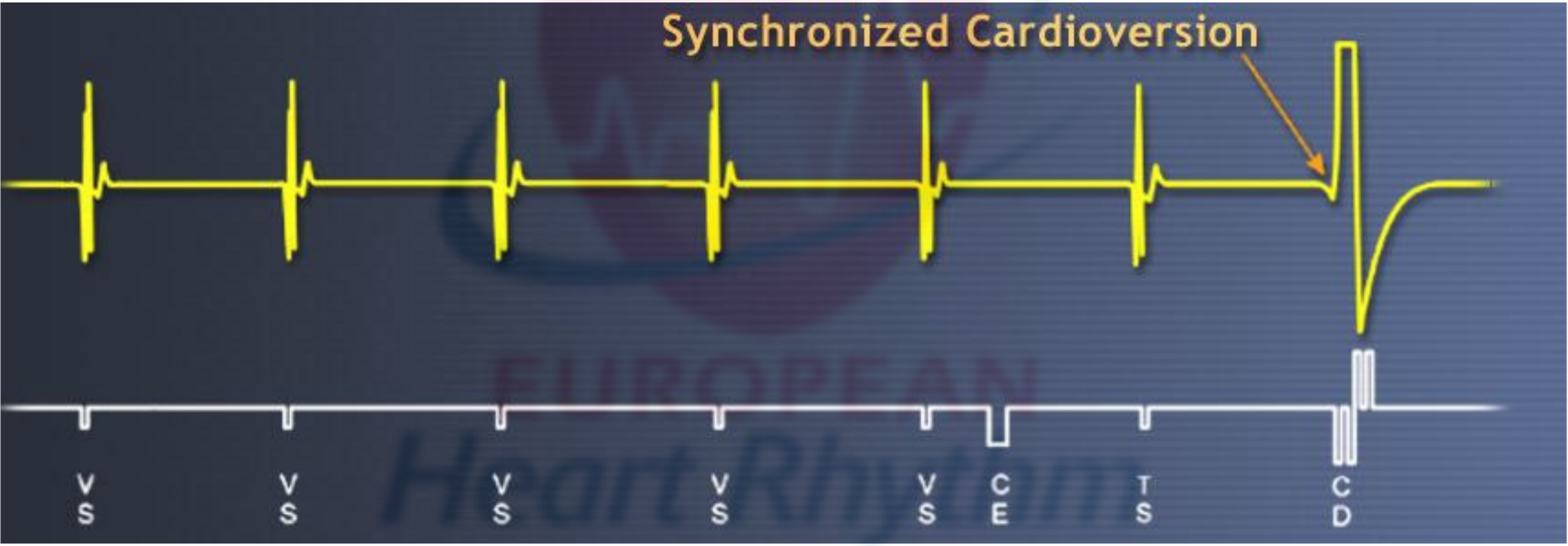


Scan



Cardioversion

- Shock synchronized to an R-wave (to avoid inducing VF)



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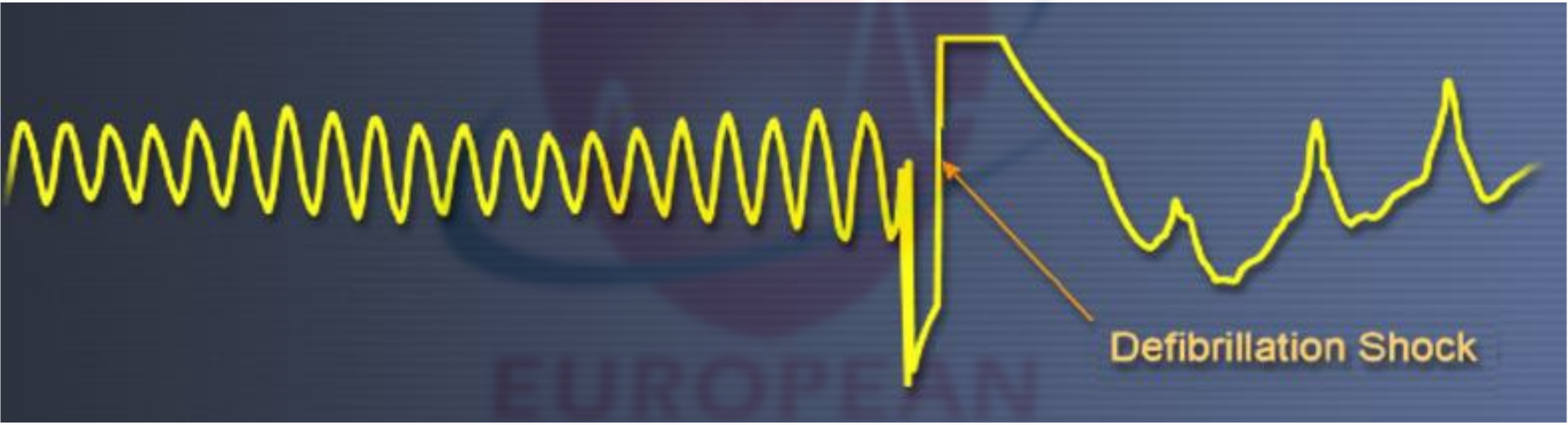
Defibrillation

Shock not synchronized to R-wave



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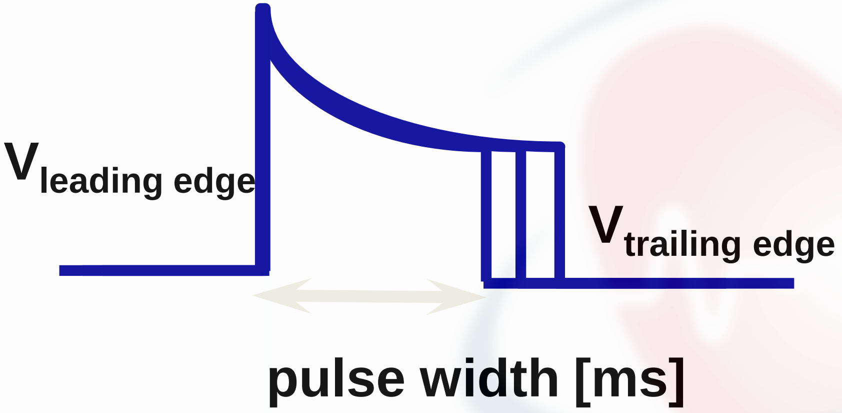
Defibrillation Threshold - DFT

- DFT is the lowest shock energy at which Ventricular Fibrillation (VF) is reliably converted into sinus rhythm
  - The delivered shock is often expressed in energy (Joules), but can also be expressed in voltage (Volts)
- Common practice is to test defibrillation with a 10J safety margin (from maximum possible ICD energy) with 2 successful VF conversions
- Necessity to test DFTs for primary prevention indications is controversial

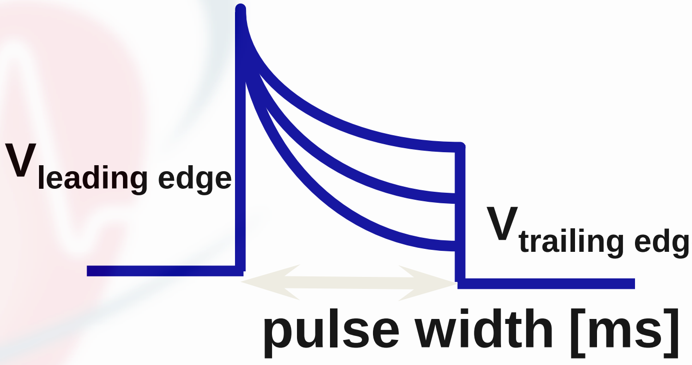
Shock waveforms

fixed tilt



pulse width is affected by impedance, imp. ↑ then pulse width ↑

fixed pulse width

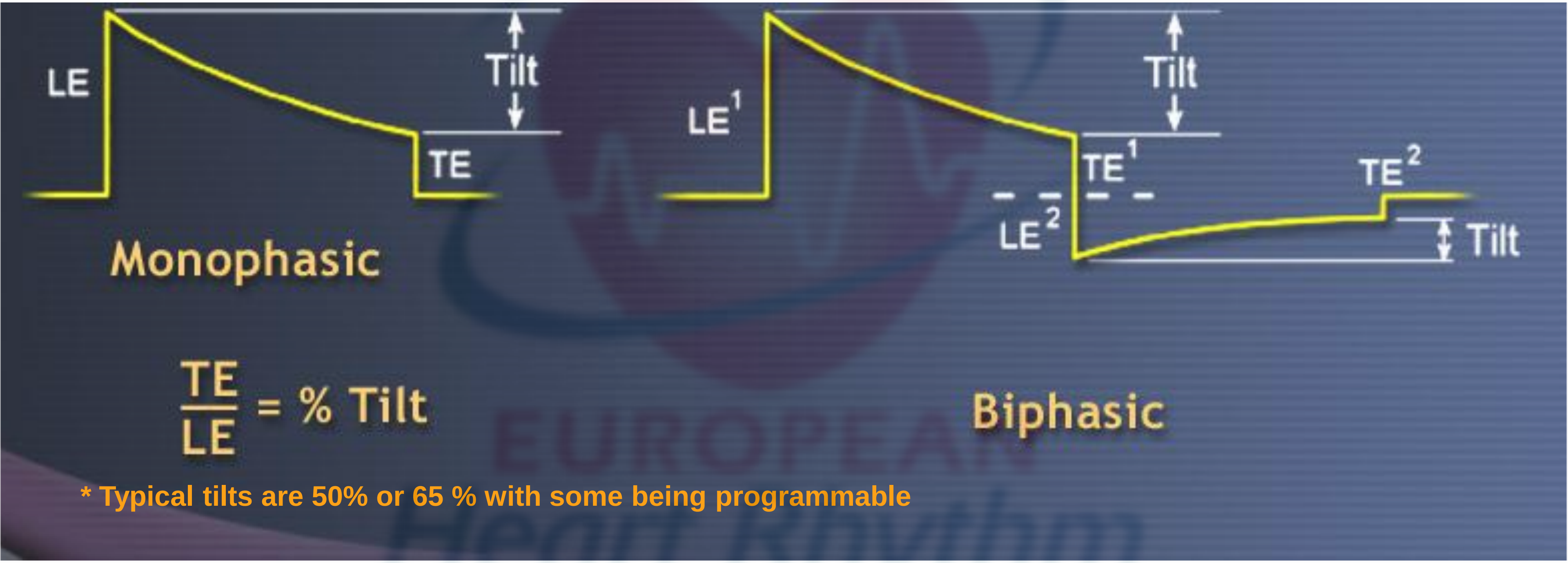


tilt is affected by impedance, impedance ↑ then tilt ↓

The first shock is always non-committed (the ICD checks for presence of VT before delivering therapy) to avoid unnecessary shocks if the patient reverts to sinus rhythm

Monophasic vs biphasic shock

Tilt = drop in Voltage

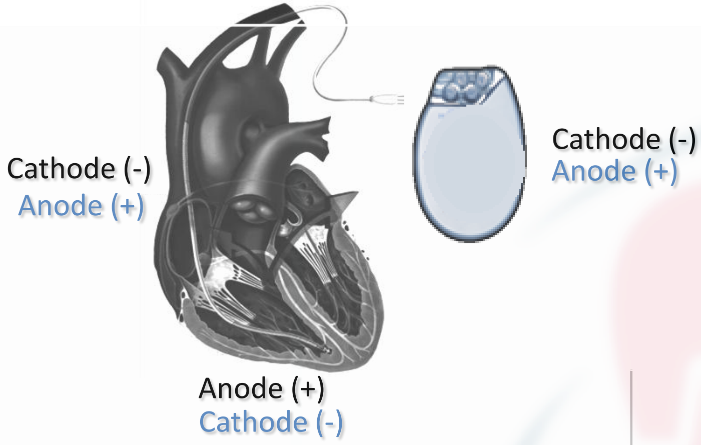


* Typical tilts are 50% or 65 % with some being programmable

ICDs have biphasic waveforms, due to lower DFTs

Source: core pace curriculum

Influence of RV Polarity on DFT



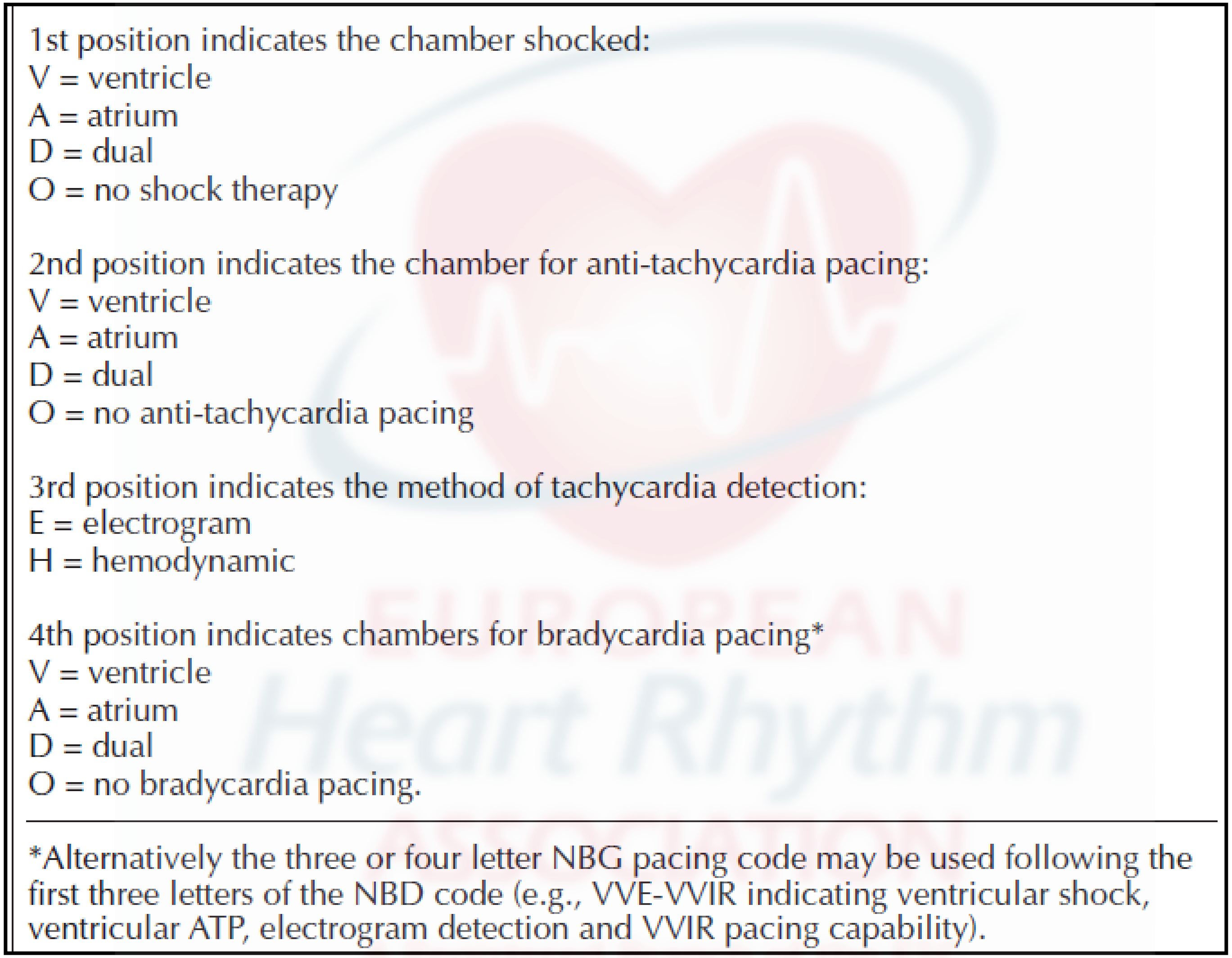
Programming of RV coil as anode or cathode depends on the model

For 88% of the patients, RV as anode is a good choice

	n	DFT RV (+)	DFT RV (-)	mean DFT reduction	RV+ better	same	RV- better
Schauerte et al, 1997	27	11.1	13.3	17%	10	14	3
Shorofsky and Gold, 1996	26	11.1	12.2	9%	-	-	-
Natale et al, 1995	20	16.3	21.5	24%	12	6	2
Strickberger et al, 1995	15	9.9	9.5	-4%	3	9	3
Keelan et al, 1997	10	6.6.	10.8	39%	7	3	0
Keelan et al, 1997	12	12	16.3	26%	7	3	2
Merged	110			16%	39	35	10
% of patients					46%	42%	12%
					88%		

Kroll MW, Tchou PJ, Testing of Implantable Defibrillator Functions at Implantation. Clinical Cardiac Pacing and Defibrillation, WB Saunders 2000.

NBD code for ICDs



1st position indicates the chamber shocked:
V = ventricle
A = atrium
D = dual
O = no shock therapy

2nd position indicates the chamber for anti-tachycardia pacing:
V = ventricle
A = atrium
D = dual
O = no anti-tachycardia pacing

3rd position indicates the method of tachycardia detection:
E = electrogram
H = hemodynamic

4th position indicates chambers for bradycardia pacing*
V = ventricle
A = atrium
D = dual
O = no bradycardia pacing.

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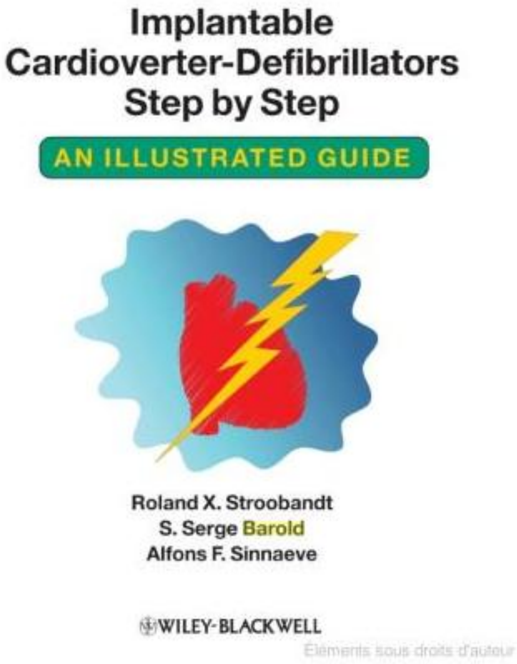
*Alternatively the three or four letter NBG pacing code may be used following the first three letters of the NBD code (e.g., VVE-VVIR indicating ventricular shock, ventricular ATP, electrogram detection and VVIR pacing capability).

Suggested reading



Implantable Cardioverter-Defibrillators Step by Step

AN ILLUSTRATED GUIDE

Roland X. Stroobandt
S. Serge Barold
Alfons F. Sinnaeve

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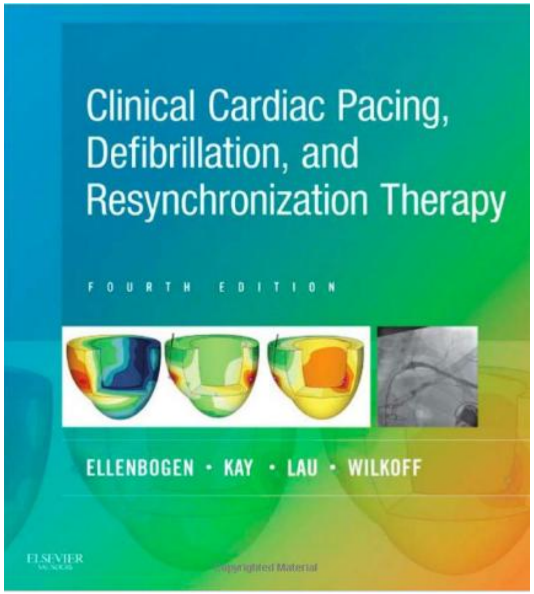

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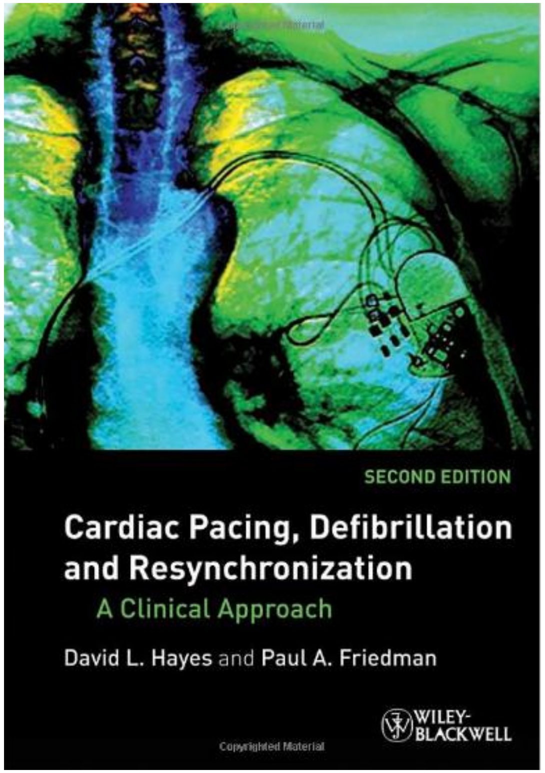

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A Clinical Approach

David L. Hayes and Paul A. Friedman

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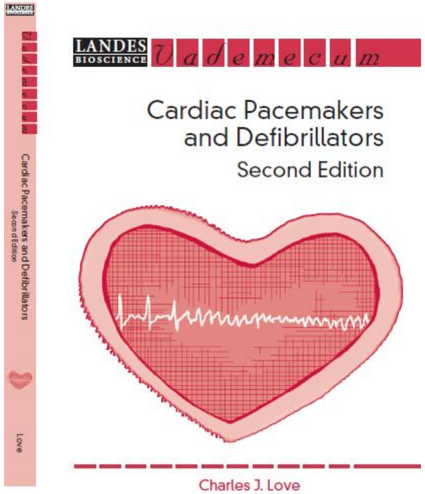

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Second Edition

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